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COMMUNICATION

Silver-catalyzed [3+2]-cycloaddition of benzynes with diazocarbonyl species *via* a postulated (1*H*-indazol-1-yl)silver intermediate†

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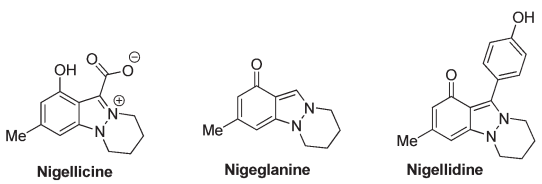
We reported a new synthesis of 2-aryl-2*H*-indazoles *via* a silver-catalyzed [3+2]-cycloaddition of benzynes with diazocarbonyl reagents. We postulate that this transformation involves the generation of (1*H*-indazol-1-yl)silver to activate a subsequent arylation with the second benzyne.

Introduction

The synthesis of indazole derivatives has attracted considerable attention because many naturally occurring compounds possess such a motif[1] including nigellicine,[1b,c] nigeglanine,[1d] and nigellidine,[1e] as shown in Scheme 1. More importantly, indazole derivatives have found widespread applications in pharmaceuticals because of their potent bioactivities[2] such as anti-cancer,[3,5] HIV protease inhibition[4] and anti-platelet activities.[6]

Among the reported syntheses of indazole derivatives,[7–11] [3+2]-cycloadditions of benzynes with diazocarbonyl reagents[9–11] appear to be appealing and efficient because of their convenient operations under mild conditions; general reaction protocols are provided in Scheme 2. For α-substituted diazocarbonyl esters, their reactions with benzynes afforded 2-acylindazole products **I** *via* a 1,2-acyl shift of intermediates **A**.[9f] For unsubstituted diazo species, their resulting intermediates **B** underwent a 1,3-hydrogen shift to give indazole species **II** that further reacted with benzyne to give 1-phenylindazole products



Scheme 1 Selected naturally occurring compounds.

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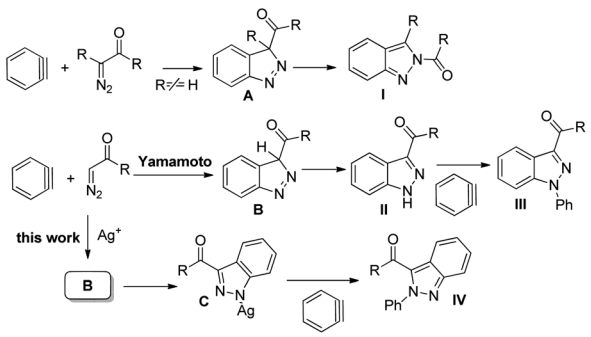


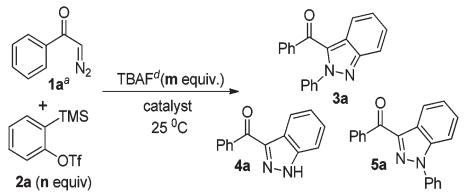
Scheme 2 Reaction protocols in the presence or absence of Ag^+.

III.[10,11] In this work, we assess the presence of Ag(I) ions to affect intermediate **B**, giving distinct 2-phenylindazole species **IV**. We postulate that the change of reaction chemoselectivity is attributed to the formation of (1*H*-indazol-1yl)silver **C** *via* an interception of initial intermediate **B**.

Results and discussion

Shown in Table 1 is the effect of metal ions on the [3+2]-cycloadditions of diazocarbonyl species **1a** with benzyne precursor **2a**.[12] Our initial goal is to study the feasibility of gold–benzyne species toward a nucleophilic attack of a diazo species **1a**. As shown in entry 1, the treatment of diazo species **1a** with benzyne precursor **2a** (2.2 equiv.), tetrabutylammonium fluoride (TBAF, 3 equiv.) and PPh_3AuOTf (5 mol%) in dichloromethane (DCM, 25 °C, 10 h) gave 2-phenylindazole **3a** in 40% yield, together with unreacted diazo **1a** in 25% yield. Under the same conditions, the use of $AgSbF_6$ and AgOTf, each at 5 mol%, gave 2-phenylindazole **3a** in increased yields of 55% and 72% respectively (entries 2 and 3). For AgOTf, an increasing proportion of species **2a** (3 equiv.) and TBAF (4 equiv.) enabled a complete conversion of starting diazo species **1a** into 2-phenylindazole **3a** with the yield of up to 80%. With these reagent proportions, both CuBr and $Cu(OTf)_2$ showed poor chemoselectivities (entries 5 and 6), giving 1- and 2-phenylindazoles **5a** (50–60%) and **3a** (5–10%) in addition to unsubstituted indazole **4a**[13] (30%). For other solvents (entries 7–10), the reactions with an AgOTf catalyst proceeded also efficiently in

Table 1 Effects of metal on reaction chemoselectivity



Entry	*n*	*m*	Catalyst[b]	Solvent	Time (h)	Compounds[c] (yield, %)
1	2.2	3	$AuClPPh_3$/AgOTf	DCM	10	**1a** (25), **3a** (40)
2	2.2	3	$AgSbF_6$	DCM	10	**1a** (17), **3a** (55)
3	2.2	3	AgOTf	DCM	10	**1a** (15), **3a** (72)
4	3	4	AgOTf	DCM	4	**3a** (80)
5	3	4	CuBr	DCM	4	**3a** (5), **4a** (30), **5a** (60)
6	3	4	$Cu(OTf)_2$	DCM	4	**3a** (10), **4a** (30), **5a** (50)
7	3	4	AgOTf	DCE	10	**1a** (15), **3a** (42)
8	3	4	AgOTf	THF	4	**3a** (65), **5a** (12)
9	3	4	AgOTf	CH_3CN	4	**3a** (74)
10	3	4	—	THF	4	**4a** (32), **5a** (45%)

[a] [**1a**] = 0.1 M. [b] 5 mole%. [c] Product yields are reported after separation from a silica column. [d] TBAF = 1.0 M solution in THF.

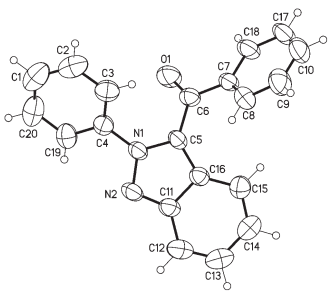
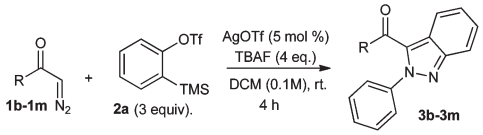


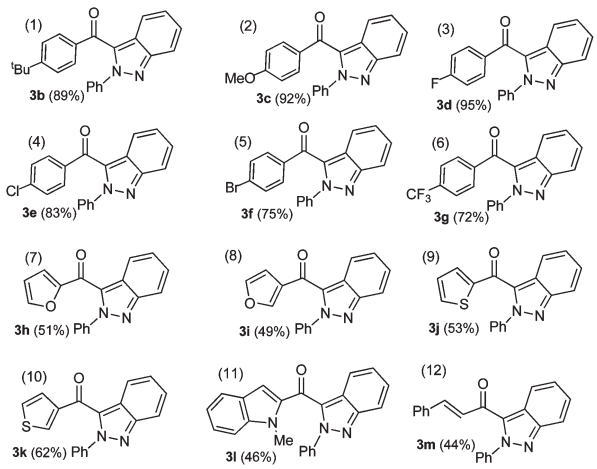
Fig. 1 ORTEP drawing of compound **3a**.

CH_3CN (74% **3a**), but less satisfactorily in dichloroethane (42% **3a**) and THF (65% **3a**). In the absence of a catalyst, we only obtained 3-carbonylindazole **4a** (32%) and 1-phenyl-3-carbonylindazole species **5a** (45%), consistent with Yamamoto's observation.[11] The molecular structure of 2-phenyl-3-carbonylindazole **3a** was confirmed by an X-ray diffraction study;[14] its ORTEP drawing is shown in Fig. 1. Compound **3a** showed ^{1}H NMR resonances within 7.0–8.0 ppm whereas its regioisomer **5a** exhibited two doublets in downfield regions (8.3–8.6 ppm).

We prepared various diazocarbonyl species **1b–1m** to test the scopes of diazo reagents; the results are depicted in Table 2. Herein, resulting products **3b–3m** showed ^{1}H NMR patterns resembling those of parent analogue **3a**. Entries 1–6 show the applicability of this silver-catalyzed reaction to diazo substrates **1b–1g** bearing either an electron-rich or -deficient phenyl substituent (R = *tert*-butyl, methoxy, fluoro, chloro, bromo and thifluoromethyl), giving expected 2-phenyl-3-carbonylindazoles **3b–3g** in 72–95% yields. We also prepared heteroaryl ketone diazo species **1h–1k** including 1- or 2-furanyl and -thienyl substituents; their silver catalytic reactions with benzynes afforded

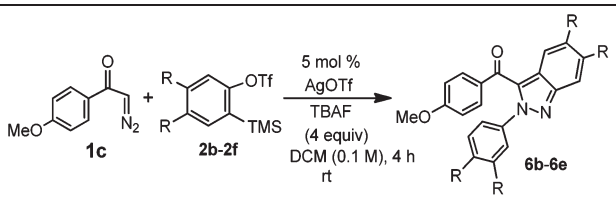
Table 2 Reactions over various α-carbonyldiazo species[a,b]





[a] [**1**] = 0.1 M. [b] Product yields are reported after separation from a silica column.

Table 3 Reactions with various benzyne precursors[a,b]

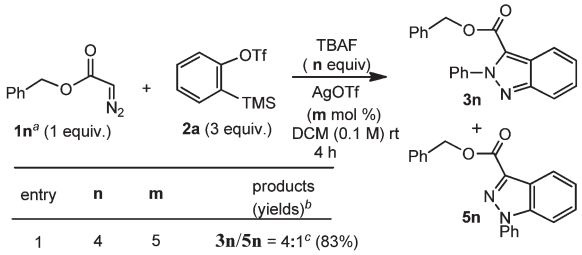


Entry	Benzyne	Compounds (yields, %)
1	R = Me (**2b**)	**6b** (76%)
2	R, R = $-(CH_2)_3-$ (**2c**)	**6c** (72%)
3	R = F (**2d**)	**6d** (70%)
4	R = Cl (**2e**)	**6e** (82%)
5	R = OMe (**2f**)	Complicated mixture

[a] [**1**] = 0.1 M, **2** (3 equiv.). [b] Product yields are reported after separation from a silica column.

2-phenyl-3-carbonylindazoles **3h–3k** in 49–62% yields (entries 7–10). We also tested the reaction on 2-indolylketone diazo species **1l** (entry 11) that gave desired 2-phenyl-3-carbonylindazole **3l** in 46% yield. This reaction also worked for an alkenylketone diazo derivative, producing 2-phenylindazole **3m** in 44% yield (entry 12).

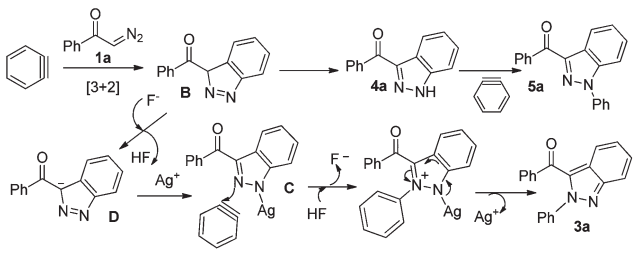
Table 3 shows the results for the silver-catalyzed reactions of diazo species **1c** with various *o*-(trimethylsilyl)aryl triflates **2b–2f** under the same conditions. For precursors **2b** and **2c**, their corresponding 2-phenyl-3-carbonylindazoles **6b** and **6c** were obtained in 76% and 72% yields respectively (entries 1 and 2). The reactions worked well for precursors bearing difluoro- and



entry	n	m	products (yields)[b]
1	4	5	**3n**/**5n** = 4:1[c] (83%)
2	4	10	**3n**/**5n** = 5:1 (72%)
3	5	5	**3n**/**5n** = 4.3:1 (80%)

[a] [**1n**] = 0.1 M. [b] product yields are reported after separation from a silica column [c] ratio determined by ^{1}H NMR

Scheme 3 Effects of fluorides and AgOTf.



Scheme 4 A plausible reaction route.

dichloro groups, giving desired 2-phenyl-3-carbonylindazoles **6d** and **6e** in satisfactory yields. In contrast, the reaction was not compatible with electron-rich benzyne like species **2f**, leading to products with complicated mixtures.

Shown in Scheme 3 are our efforts to improve the chemoselectivity of diazo ester species **1n**; this process may enable us to understand the reaction mechanism. Treatment of starting **1n** with benzyne precursor **2a** (3 equiv.), TBAF (4 equiv.) and AgOTf (5 mol%) in DCM (25 °C, 4 h) gave a mixture of 2- and 1-phenyl-3carbonylindazoles **3n** and **5n** (83%, **3n** : **5n** = 4 : 1). The use of a high AgOTf loading (10 mol%) increased the **3n** : **5n** ratio to 5 : 1 (entry 2), compatible with our expectation. On the other hand, an increased amount of TBAF (5 equiv., entry 3) assisted also the production of desired 2-phenyl-3-carbonylindazole **3n** with **3n** : **5n** = 4.3 : 1. Accordingly, increasing loadings of TBAF and AgOTf are helpful to produce desired **3a**.

Scheme 4 shows a plausible mechanism to account for the effect of Ag^+ and fluoride on the reaction chemoselectivity. The initial [3+2]-cycloaddition reaction between diazo species **1a** and benzyne presumably produced 3-acyl-3*H*-indazole **B**. In the absence of Ag(I), this species will undergo a slow 1,3-hydrogen shift to give 3-carbonyl-indazole **4a** that further reacts with benzyne to give 1-phenyl-3-carbonylindazole **5a**. We postulate that species **B** is quite acidic and readily deprotonated by fluoride to give a carbonyl-stabilized anion **D** that can be trapped by Ag(I) to give (1*H*-indazol-1-yl)silver **C**. Its reaction with benzyne is expected to form distinct arylation product **3a**. Accordingly, formation of compound **3a** is highly dependent on the concentration of both fluoride and Ag(I) ions, consistent with our observation in Scheme 3.

Conclusions

In summary, we have developed a new approach toward the synthesis of 2-aryl-2*H*-3-carbonylindazole with the use of AgOTf. This reaction shows distinct chemoselectivity from those reported earlier by Yamamoto *et al.*[11] We postulate that the role of the Ag(+) ion is to intercept the initially formed 3-acyl-3*H*-indazole intermediate under the action of fluoride; this process is postulated to give (1*H*-indazol-1-yl)silver **C**. Further application of this work toward the synthesis of bioactive molecules is under current investigation.

Experimental

General methods

Unless otherwise noted, all reactions were carried out under a nitrogen atmosphere in oven-dried glassware using a standard syringe, a cannula and a septa apparatus. Tetrahydrofuran and hexane were dried with sodium benzophenone and distilled before use. Dichloromethane, 1,2-dichloroethane and acetonitrile were dried over CaH_2 and distilled before use. ^{1}H NMR and ^{13}C NMR spectra were recorded on varian 400 MHz and Bruker 400 MHz spectrometers using $CDCl_3$ as the internal standard.

Synthesis of phenyl(2-phenyl-2*H*-indazol-3-yl)methanone (3a). To a dichloromethane solution (1.4 mL) of AgOTf (4.39 mg, 5 mol%) was added a DCM solution (1 mL) of 2-diazo-1-phenylethanone (**1a**, 50 mg, 0.34 mmol) and 2-(trimethylsilyl)-phenyltrifluoromethanesulfonate (**2a**, 306 mg, 1.02 mmol); the mixture was stirred briefly for 5 min before it was added to a dichloromethane solution (1 mL) of TBAF (1.37 mL, 1 M in THF) *via* a syringe pump over a period of 4 h. The mixture was stirred for an additional 0.5 h before it was concentrated and eluted through a silica column (hexane–EA = 30 : 1) to afford compound **3a** (81 mg, 80%) as a white solid; mp: 163–165 °C; IR (neat, cm^{-1}): 3172, 1660, 1593, 765; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88–7.84 (m, 3 H), 7.61–7.56 (m, 1 H), 7.53–7.51 (m, 2 H), 7.46–7.34 (m, 7 H), 7.18–7.14 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 185.8, 148.4, 140.4, 137.7, 133.4, 132.1, 129.8, 128.9, 128.8, 128.5, 126.9, 125.4, 124.9, 123.9, 120.5, 118.4; HRMS calcd for $C_{20}H_{14}N_2O$: 298.1106, found: 298.1104.

Spectral data for (4-*tert*-butylphenyl)(2-phenyl-2*H*-indazol-3-yl)methanone (3b). White solid; mp: 124–125.7 °C; IR (neat, cm^{-1}): 3170, 1658, 1587, 834; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, J = 8.8 Hz, 1 H), 7.83–7.80 (m, 2 H), 7.52–7.50 (m, 2 H), 7.47–7.44 (m, 2 H), 7.42–7.34 (m, 5 H), 7.19–7.15 (m, 1 H), 1.34 (s, 9 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 185.5, 157.5, 148.4, 140.4, 134.9, 132.4, 129.9, 128.9, 128.6, 126.8, 125.5, 125.3, 124.6, 123.7, 120.5, 118.3, 35.1, 30.9; HRMS calcd for $C_{24}H_{22}N_2O$: 354.1732, found: 354.1730.

Spectral data for (4-methoxyphenyl)(2-phenyl-2*H*-indazol-3-yl)methanone (3c). Yellow solid; mp: 126.6–128.2 °C; IR (neat, cm^{-1}): 3152, 1643, 1552, 841; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88 (d, J = 8.8 Hz, 2 H), 7.85 (d, J = 8.8 Hz, 1 H), 7.54–7.51 (m, 2 H), 7.43–7.34 (m, 5 H), 7.15 (dd, J = 6.8, 7.6 Hz, 1 H), 6.93 (d, J = 8.8 Hz, 2 H), 3.87 (s, 3 H); ^{13}C NMR (100 MHz,

$CDCl_3$): δ 184.5, 164.0, 148.3, 140.3, 132.4, 132.3, 130.3, 128.9, 128.6, 126.8, 125.2, 124.4, 123.6, 120.4, 118.2, 113.8, 55.4; HRMS calcd for $C_{21}H_{16}N_2O_2$: 328.1212, found: 328.1211.

Spectral data for (4-fluorophenyl)(2-phenyl-2*H*-indazol-3-yl)-methanone (3d). White solid; mp: 198–202 °C; IR (neat, cm^{-1}): 3144, 1650, 1493, 1222, 830; ^1H NMR (400 MHz, $CDCl_3$): δ 7.89–7.86 (m, 3 H), 7.52–7.49 (m, 2 H), 7.44–7.36 (m, 5 H), 7.21–7.17 (m, 1 H), 7.13–7.09, (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 184.3, 165.9 (d, J = 255 Hz), 148.5, 140.3, 134.0 (d, J = 3 Hz), 132.5 (d, J = 10 Hz), 131.9, 129.0, 128.9, 127.0, 125.4, 125.1, 123.9, 120.3, 118.5, 115.8 (d, J = 22 Hz); HRMS calcd for $C_{20}H_{13}FN_2O_2$: 316.1012, found: 316.1014.

Spectral data for (4-chlorophenyl)(2-phenyl-2*H*-indazol-3-yl)-methanone (3e). Yellow solid; mp: 181.5–185.3 °C; IR (neat, cm^{-1}): 3180, 1673, 1590, 1094, 862; ^1H NMR (400 MHz, $CDCl_3$): δ 7.87 (dd, J = 0.8, 8.8 Hz, 1 H), 7.80–7.77 (m, 2 H), 7.51–7.49 (m, 2 H), 7.43–7.35 (m, 5 H), 7.38–7.35 (m, 2 H), 7.21–7.17 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 184.5, 148.5, 140.2, 139.9, 136.0, 131.7, 131.1, 129.0, 128.9, 128.9, 127.0, 125.4, 125.2, 123.9, 120.2, 118.5; HRMS calcd for $C_{20}H_{13}ClN_2O$: 332.0716, found: 332.0118.

Spectral data for (4-bromophenyl)(2-phenyl-2*H*-indazol-3-yl)-methanone (3f). Yellow solid; mp: 155–160.8 °C; IR (neat, cm^{-1}): 3164, 1669, 1573, 1067, 870; ^1H NMR (400 MHz, $CDCl_3$): δ 7.87 (d, J = 8.8 Hz, 1 H), 7.73–7.70 (m, 2 H), 7.60–7.57 (m, 2 H), 7.51–7.48 (m, 1 H), 7.44–7.35 (m, 5 H), 7.21–7.17 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 184.6, 148.4, 140.2, 136.4, 131.9, 131.6, 131.2, 129.0, 128.9, 128.7, 127.0, 125.4, 125.2, 123.9, 120.2, 118.5; HRMS calcd for $C_{20}H_{13}BrN_2O$: 376.0211, found: 376.0210.

Spectral data for (2-phenyl-2*H*-indazol-3-yl)(4-(trifluoro-methyl)phenyl)methanone (3g). White solid; mp: 154.3–156.6 °C; IR (neat, cm^{-1}): 3189, 1694, 1592, 1325, 854; ^1H NMR (400 MHz, $CDCl_3$): δ 7.91 (t, J = 8 Hz, 3 H), 7.68 (d, J = 8.4 Hz, 2 H), 7.05–7.48 (m, 2 H), 7.42–34 (m, 5 H), 7.23–7.20 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 184.5, 148.6, 140.7, 140.3, 134.5 (d, J = 33 Hz), 131.5, 130.0, 129.1, 129.1, 127.2, 125.6, 125.6, 125.5, 124.2, 123.4 (d, J = 271 Hz), 120.2, 118.7; HRMS calcd for $C_{21}H_{13}F_3N_2O$: 366.0980, found: 366.0985.

Spectral data for furan-2-yl(2-phenyl-2*H*-indazol-3-yl)metha-none (3h). Yellow solid; mp: 138–140.5 °C; IR (neat, cm^{-1}): 1650, 1592, 764; ^1H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, J = 8.4 Hz, 1 H), 7.69 (d, J = 8.4 Hz, 1 H), 7.55 (s, 1 H), 7.54 (d, J = 8 Hz, 2 H), 7.43–7.35 (m, 4 H), 7.25–7.19 (m, 2 H), 6.51 (dd, J = 1.6, 3.6 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 152.1, 148.5, 147.5, 140.4, 131.5, 129.0, 128.7, 127.0, 125.1, 124.9, 123.7, 120.9, 120.3, 118.3, 112.6; HRMS calcd for $C_{18}H_{12}N_2O_2$: 288.0899, found: 288.0892.

Spectral data for furan-3-yl(2-phenyl-2*H*-indazol-3-yl)metha-none (3i). Yellow solid; mp: 170–173 °C; IR (neat, cm^{-1}): 1662, 1587, 772; ^1H NMR (400 MHz, $CDCl_3$): δ 7.90 (d, J = 0.8 Hz, 1 H), 7.84 (d, J = 8.8 Hz, 1 H), 7.66 (d, J = 8.8 Hz, 1 H), 7.54–7.51 (m, 2 H), 7.45–7.34 (m, 5 H), 7.23–7.19 (m, 1 H), 6.81 (d, J = 0.8 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 178.6, 149.7, 148.5, 144.3, 140.2, 132.7, 129.0, 128.9, 127.8, 127.0, 125.3, 124.8, 123.2, 120.1, 118.4, 109.4; HRMS calcd for $C_{18}H_{12}N_2O_2$: 288.0899, found: 288.0893.

Spectral data for (2-phenyl-2*H*-indazol-3-yl)(thiophen-2-yl)-methanone (3j). Yellow solid; mp: 175.3–176 °C; IR (neat, cm^{-1}): 1658, 1573, 1524, 748; ^1H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, J = 8.8 Hz, 1 H), 7.76–7.74 (m, 1 H), 7.65–7.63 (m, 2 H), 7.61–7.54 (m, 2 H), 7.45–7.36 (m, 4 H), 7.23–7.19 (m, 1 H), 7.12–7.10 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 177.8, 148.5, 144.1, 140.2, 135.5, 135.4, 132.0, 129.1, 128.9, 128.2, 127.0, 125.3, 124.8, 123.4, 120.3, 118.4; HRMS calcd for $C_{18}H_{12}N_2OS$: 304.0670, found: 304.0673.

Spectral data for (2-phenyl-2*H*-indazol-3-yl)(thiophen-3-yl)-methanone (3k). Yellow solid; mp: 155.7–157.4 °C; IR (neat, cm^{-1}): 1660, 1569, 1520, 752; ^1H NMR (400 MHz, $CDCl_3$): δ 7.99 (dd, J = 1.2, 2.8 Hz, 1 H), 7.86 (d, J = 8.8 Hz, 1 H), 7.55–7.52 (m, 4 H), 7.44–31 (m, 5 H), 7.21–7.17 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 179.1, 148.4, 142.0, 140.3, 135.0, 132.7, 129.0, 128.8, 127.7, 126.9, 126.6, 125.3, 124.8, 123.5, 120.3, 118.4; HRMS calcd for $C_{18}H_{12}N_2OS$: 304.0670, found: 304.0671.

Spectral data for (1-methyl-1*H*-indol-2-yl)(2-phenyl-2*H*-indazol-3-yl)methanone (3l). Yellow solid; mp: 175–178.7 °C; IR (neat, cm^{-1}): 3161, 1655, 1622, 1585, 763; ^1H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, J = 8.8 Hz, 1 H), 7.67–7.58 (m, 4 H), 7.47–7.36 (m, 6 H), 7.25 (s, 1 H), 7.20–7.14 (m, 2 H), 4.09 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 177.2, 148.4, 140.9, 140.5, 135.6, 133.2, 129.1, 128.8, 126.9, 126.7, 125.8, 125.2, 124.5, 123.6, 123.3, 121.0, 120.8, 118.2, 116.0, 110.4, 31.9; HRMS calcd for $C_{23}H_{17}N_3O$: 351.1372, found: 351.1366.

Spectral data for (*E*)-3-phenyl-1-(2-phenyl-2*H*-indazol-3-yl) prop-2-en-1-one (3m). Yellow oil; IR (neat, cm^{-1}): 3174, 3062, 1680, 1554, 752; ^1H NMR (400 MHz, $CDCl_3$): δ 8.05 (dd, J = 0.8, 8.8 Hz, 1 H), 7.87 (dd, J = 0.8, 8.8 Hz, 1 H), 7.72 (d, J = 16 Hz, 1 H), 7.60–7.50 (m, 5 H), 7.44–7.32 (m, 7 H), 6.99 (d, J = 16 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 181.4, 148.6, 144.5, 140.8, 134.3, 133.8, 130.8, 129.4, 129.2, 128.9, 128.4, 127.2, 126.1, 125.6, 124.8, 123.8, 120.9, 118.6; HRMS calcd for $C_{22}H_{16}N_2O$: 324.1263, found: 324.1268.

Spectral data for (2-(3,4-dimethylphenyl)-5,6-dimethyl-2*H*-indazol-3-yl)(4-methoxyphenyl)methanone (6b). White solid; mp: 135–136.7 °C; IR (neat, cm^{-1}): 3159, 1658, 1579, 852; ^1H NMR (400 MHz, $CDCl_3$): δ 7.87 (d, J = 8.8 Hz, 2 H), 7.58 (s, 1 H), 7.33 (d, J = 2.4 Hz, 1 H), 7.15–7.08 (m, 3 H), 6.92 (d, J = 8.8 Hz, 2 H), 3.87 (s, 3 H), 2.37 (s, 3 H), 2.25 (s, 3 H), 2.24 (s, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 184.8, 163.9, 148.1, 138.3, 137.5, 137.1, 137.1, 134.7, 132.4, 131.3, 130.7, 129.9, 126.1, 122.8, 122.5, 118.9, 116.9, 113.8, 55.5, 20.8, 20.6, 19.7, 19.4; HRMS calcd for $C_{25}H_{24}N_2O_2$: 384.1838, found: 384.1840.

Spectral data for (2-(2,3-dihydro-1*H*-inden-5-yl)-2,5,6,7-tetra-hydrocyclopenta[*f*]indazol-3-yl)(4-methoxyphenyl)methanone (6c). White solid; mp: 164.2–166 °C; IR (neat, cm^{-1}): 3168, 1651, 1568, 849; ^1H NMR (400 MHz, $CDCl_3$): δ 7.88 (d, J = 8.8 Hz, 2 H), 7.60 (s, 1 H), 7.37 (s, 1 H), 7.18 (s, 2 H), 7.12 (s, 1 H), 6.93 (d, J = 8.8 Hz, 2 H), 2.97 (dt, J = 0.8, 7.2 Hz, 2 H),

2.90–2.84 (m, 6 H), 2.10–2.03 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 184.9, 163.8, 148.7, 145.2, 145.1, 144.7, 142.7, 138.9, 132.4, 131.5, 130.8, 124.4, 123.5, 123.2, 121.2, 113.8, 113.8, 112.0, 55.5, 32.7, 32.6, 32.5, 32.4, 26.4, 25.5; HRMS calcd for $C_{27}H_{24}N_2O_2$: 408.1838, found: 408.1840.

Spectral data for (2-(3,4-difluorophenyl)-5,6-difluoro-2*H*-indazol-3-yl)(4-methoxyphenyl)methanone (6d). White solid; mp: 110–112.3 °C; IR (neat, cm^{-1}): 3147, 1666, 1579, 1231, 855; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82 (d, J = 8.8 Hz, 2 H), 7.52 (dd, J = 6.4, 9.6 Hz, 1 H), 7.44–7.39 (m, 1 H), 7.21–7.17 (m, 2 H), 7.07 (dd, J = 8.0, 10 Hz, 1 H), 6.96 (d, J = 8.8 Hz, 2 H), 3.89 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 183.6, 164.6, 153.4–148.7 (m, 4C), 144.5 (d, J = 11 Hz), 136.2 (dd, J = 3, 8 Hz), 133.3 (d, J = 6 Hz), 132.3, 129.6, 121.4 (dd, J = 4, 6 Hz), 119.3(d, J = 20 Hz), 117.5 (d, J = 18 Hz), 115.0 (d, 20 Hz), 114.3, 105.7 (dd, J = 1, 22 Hz), 104.1 (dd, J = 1, 22 Hz), 55.6; HRMS calcd for $C_{21}H_{12}F_4N_2O_2$: 400.0835, found: 400.0837.

Spectral data for (5,6-dichloro-2-(3,4-dichlorophenyl)-2*H*-indazol-3-yl)(4-methoxyphenyl)methanone (6e). White solid; mp: 153–156.2 °C; IR (neat, cm^{-1}): 3168, 1672, 1598, 1089, 858; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.96 (s, 1 H), 7.83 (d, J = 8.0 Hz, 2 H), 7.69 (dd, J = 0.8, 2.4 Hz, 1 H), 7.50 (s, 1 H), 7.47 (dd, J = 0.8, 8.8 Hz, 1 H), 7.32–7.29 (m, 1 H), 6.98 (d, J = 8.0 Hz, 2 H), 3.91 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 183.4, 164.8, 147.0, 139.0, 133.6, 133.4, 132.5, 132.5, 132.4, 130.7, 129.9, 129.6, 127.1, 124.3, 122.4, 121.2, 119.4, 114.4, 55.7; HRMS calcd for $C_{21}H_{12}Cl_4N_2O_2$: 463.9643, found: 463.9645.

Spectral data for (1*H*-indazol-3-yl)(phenyl)methanone (4a). White solid; mp: 188.3–191 °C; IR (neat, cm^{-1}): 3182, 1628, 1492, 740; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.45 (d, J = 8.0 Hz, 1 H), 8.27 (dd, J = 0.8, 8.0 Hz, 2 H), 7.61–7.34 (m, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 189.1, 140.7, 137.8, 132.5, 130.3, 128.1, 128.0, 127.6, 123.7, 123.4, 122.9, 109.8; HRMS calcd for $C_{14}H_{10}N_2O$: 222.0793, found: 222.0795.

Spectral data for phenyl(1-phenyl-1*H*-indazol-3-yl)methanone (5a). White solid; mp: 142.5–145.1 °C; IR (neat, cm^{-1}): 3179, 1642, 1580, 735; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.56 (d, J = 8.4 Hz, 1 H), 8.42 (d, J = 8.4 Hz, 2 H), 7.78–7.76 (m, 3 H), 7.61–7.40 (m, 8 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 188.5, 143.4, 139.8, 139.4, 137.7, 132.5, 130.6, 129.5, 128.1, 127.8, 127.7, 125.4, 124.1, 123.4, 123.4, 110.6; HRMS calcd for $C_{20}H_{14}N_2O$: 298.1106, found: 298.1104.

Spectral data for benzyl 2-phenyl-2*H*-indazole-3-carboxylate (3n) and benzyl 1-phenyl-1*H*-indazole-3-carboxylate (5n). White solid; mp: 127.5–130.6 °C; IR (neat, cm^{-1}): 3125, 1665, 1586, 763; ^{1}H NMR (400 MHz, $CDCl_3$): (**3n**) select peaks: δ 8.08 (d, J = 8.4 Hz, 1 H), 7.84 (d, J = 8.8 Hz, 1 H), 5.33 (s, 2 H); (**5n**) select peaks: δ 8.27 (d, J = 8.4 Hz, 1 H), 7.85–7.69 (m, 3 H), 5.53 (s, 2 H), other peaks are overlapped; ^{13}C NMR (100 MHz, $CDCl_3$): (**3n**) δ 159.1, 148.3, 140.9, 135.2, 129.3, 128.6, 128.5, 128.3, 128.2, 127.0, 126.3, 125.6, 124.7, 124.1, 121.4, 118.5, 66.7; (**5n**) δ 162.4, 140.2, 139.2, 136.7, 135.9, 129.4, 128.5, 128.4, 127.9, 127.5, 126.3, 124.4, 123.8, 123.7, 122.4, 110.8, 66.7; HRMS calcd for $C_{21}H_{16}N_2O_2$: 328.1212, found: 328.1215.

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